UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
CENTER FOR ENVIRONMENTAL MEASUREMENT AND MODELING
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OFFICE OF
RESEARCH AND DEVELOPMENT

May 13, 2021

Ms. Cristina Fernandez, Director
Air Protection Division
U.S. Environmental Protection Agency Region 3
1650 Arch Street
Mail Code: 3AP00
Philadelphia, PA 19103-2029

Subject: WV DAQ Data Report #3: Comparison of Laboratory Analytical Results for Method 0010 Sampling Trains and Emissions Estimates for HFPO-DA and PFOA at the Chemours Washington Works Facility

Dear Director Fernandez:

I am pleased to provide the enclosed third report from our ongoing collaborative technical support to the West Virginia Division of Air Quality (WVDAQ) assisting with questions about environmental contamination associated with per- and polyfluoroalkyl substances (PFAS) that may have occurred via air emissions from the Chemours Washington Works facility near Parkersburg, West Virginia.

This report is in response to an August 2018 request from WVDAQ asking for laboratory assistance analyzing PFAS in samples collected during air emission testing at the Chemours facility. The enclosed Report #3 provides a comparison of laboratory results for PFAS found in air emission samples collected by Chemours contractors using EPA Method 0010 (MM-0010) as analyzed by the commercial laboratories of Test America and EPA's Office of Research and Development. This report also provides estimates of air emissions from the facility.

It is our understanding that this information was requested by WVDAQ to help in their ongoing investigation into the presence of PFAS in the environment near the manufacturing facility of interest. This request relates to our research capabilities and interests applying targeted and non-targeted analysis methods for discovery of the nature and extent of PFAS environmental occurrence that may be potentially associated with industrial releases. EPA continues to develop analytical methods for many PFAS compounds in various media including some of those included in this report.

In this report, we compare quantitative analytical results for 2 PFAS (PFOA and HFPO-DA) in 116 MM-0010 samples. We do not interpret exposure or risk from these values. While the data provided in the attached report indicates the presence (or lack) of PFAS in the samples, we do

not have sufficient information to offer interpretations related to human or environmental exposure and risk.

Thank you for inviting us to be part of this effort that helps to further both EPA's and West Virginia's understanding of an important issue in the state.

If you have any questions or concerns, do not hesitate to contact me at (919) 541-5114 or via email at watkins.tim@epa.gov or Brian Schumacher at (706) 355-8001 or via email at schumacher.brian@epa.gov.

Sincerely,

Timothy H Watkins

Timothy H. Watkins
Director

Enclosure

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PFAS Associated with Air Emission Control Devices in West Virginia

Report #3: Comparison of Laboratory Analytical Results for Method 0010 Sampling Trains and Emissions Estimates for HFPO-DA and PFOA at the Chemours Washington Works Facility

Background and Objectives

The West Virginia Division of Air Quality (WV DAQ) is evaluating per- and polyfluoroalkyl substances (PFAS) that may be generated and emitted into surrounding environmental media by air emissions from the Chemours Washington Works facility near Parkersburg, West Virginia. Chemours conducted emissions sampling at the facility in August and November 2018 to assess scrubber performance in reducing PFAS emissions. Chemours's contractor, O'Brien and Gere Engineering, Inc (OBG) conducted tests at three locations within the fluoropolymers manufacturing area using standard EPA Method 0010 (MM-0010) sampling trains to collect and identify PFAS compounds and their degradation products that may be discharged to the atmosphere after passing through scrubber control devices. Samples collected by the MM-0010 trains were tested for perfluorooctanoic acid (PFOA) and C3 dimer acid (HFPO-DA) at the commercial laboratories of Test America (now Eurofins). Test America laboratories are certified by the National Environmental Laboratory Accreditation Program (NELAP), as well as by numerous federal and state programs. Analytical results were used to estimate emissions of these two PFAS compounds from the facility and to evaluate the effectiveness of the facility's control devices to reduce emissions.

WV DAQ in coordination with EPA Region 3, requested technical support from EPA's Office of Research and Development (ORD) to provide additional analysis of the emissions of PFOA and HFPO-DA from Chemours's Washington Works facility based on the 2018 emission testing information and to identify additional PFAS that may also be present in the stack emissions. At WV DAQ's request, Test America prepared splits of the extracted samples collected in the MM-0010 trains and provided them to ORD for additional chemical analysis.

Study objectives[1] for this project included to:

- Quantify the amount of HFPO-DA and PFOA in the MM-0010 samples;
- Determine what additional PFAS are being emitted and their relative quantity in relation to the HFPO-DA;
- Determine the control efficiencies of current air pollution control devices to reduce HFPO-DA and PFOA;
- Understand the relative concentration of fluorinated compounds generated when emitting PFAS to the air; and
- Provide an independent comparison of analytical results reported by Chemours/contractors.

[1] U.S. EPA National Exposure Research Laboratory, Project Study Plan: Targeted and Non-targeted Analyses of Per- and Polyfluoroalkyl Substances (PFAS) In Air Emission Control Devices for the West Virginia Division of Air Quality (WVDAQ) D-IO-0031870-QP-1-0, 19Feb2019.

ORD has previously provided concentrations of PFOA and HFPO-DA in WV DAQ Report #1[2] meeting Objective #1 and identified additional PFAS compounds in air emission samples in WVDAQ Report #2[3] meeting Objective #2. This 3rd report provides ORD estimates of air emissions and compares laboratory and emissions estimates produced by Chemours's contractors and ORD addressing objectives 3-5.

ORD's analysis and report team that contributed to this effort are listed in Table 1.

Table 1. EPA Office of Research and Development Lab Analysis and Report Team.

Responsibility	Personnel
ORD Principal Investigators	James McCord, Mark Strynar, Jeff Ryan
Laboratory chemistry	James McCord, Ken Krebs
Quality Assurance Review	Sania Tong-Argao
Management coordination and review	Myriam Medina-Vera, Brian Schumacher
Report preparation	Kate Sullivan

Project to Date

Emissions Sampling

Emission sampling was conducted by Chemours's contractor OBG during 2 testing events (August and November 2018) at three scrubber locations (i.e., the PTFE, PFA, and FEP scrubbers) within the Washington Works facility for the purpose of identifying process emissions and determining scrubber optimization. Each emissions test consisted of 3 individual 180-minute runs using modified USEPA Method 0010 sample trains and methodologies to extract air flowing through the stacks and to recover any chemical compounds in the discharge for determination of type and amount of PFAS present. Each sampling run at an emission control point included two MM-0010 trains deployed simultaneously at the inlet and outlet of the scrubber.

Four extracted samples are produced from each MM-0010 sample train:

- Front-Half Composite (FH)-consisting of a particulate filter, and a probe, nozzle and front portion of the filter holder bell housing glassware solvent rinses,
- Back-Half Composite (BH)-consisting of an XAD-2 resin module, and the back portion of the filter holder bell housing with connecting glassware solvent rinses,
- Condensate and Impinger Contents (IMP)-consisting of the D.I. water content used to initially charge the impingers and Condensate collected during the sampling run, and

[2] WVDAQ Report #1. PFAS Associated with Air Emission Control Devices in West Virginia. Laboratory Data Report #1: Targeted Analysis of PFAS in EPA Method 0010 Sampling Trains. U.S. EPA/ORD, May 12, 2020.

[3] WVDAQ Report #2. PFAS Associated with Air Emission Control Devices in West Virginia. Laboratory Data Report #2: Non-targeted Analysis of PFAS in EPA Method 0010 Sampling Trains. U.S. EPA/ORD, May 12, 2020.

- Breakthrough XAD-2 Resin Tube (XAD)-consisting of a standard XAD-2 module placed behind the Condensate Impingers as a final quality assurance indicator of the lack of breakthrough of the HFPO-DA through the sampling train.

The sum of the four fractions represents the total amount of chemical present during each test, which is used with the measured air volume flowing through the stack or pipe to determine the emission concentrations.

Laboratory Processing

Test America received samples at their Knoxville, TN, laboratory within days after sampling was completed. Upon receipt, the sampled material was extracted from various parts of the sampling equipment following Method 0010/Method 3542 Sampling Train Preparation methods. FH, BH and XAD samples were spiked with isotope dilution internal standards (IDIS). Filters and glassware were rinsed with methanol:NH_4OH (MeOH/5% NH_4OH) to assist with solvent extraction. Additional leaching procedures for XAD and condensates followed Test America laboratory standard operating procedures pertinent to each laboratory.

Laboratory Analysis

The Test America Knoxville laboratory forwarded the prepared extracts and condensate samples to their laboratory in Denver, CO, for HFPO-DA analysis, and to their laboratory in Burlington, VT, for PFOA analysis. The Test America laboratories conducted analysis using liquid chromatography and dual mass spectroscopy and completed laboratory testing within approximately 1 month after samples were received.

At a later date, WV DAQ requested that Chemours provide samples to ORD. Sample extracts were received from Test America at ORD's laboratory in Research Triangle Park, NC, on April 3, 2019 in vials containing approximately 5 to 50 mL of extract. ORD completed targeted analysis of PFOA and HFPO-DA on October 2, 2019 and non-targeted analysis for additional PFAS on Feb 27, 2020.

Important analytical methods used by the Test America and ORD laboratories are briefly described with emphasis on factors that influence comparisons of targeted analytical results for PFOA and HFPO-DA between the two laboratories.

Quantitation of PFOA

Test America Burlington determined PFOA concentrations following EPA's Method 537 (modified) which quantitates PFOAs with calibration curves derived from authentic standards. Sample recovery was determined with the internally injected surrogate ($^{13}C_4$ PFOA). Sample concentrations (e.g., ng/L) were adjusted to the mass in sample as collected during the test (needed for emission computations) and results are reported as ng/sample or µg/sample.

ORD analyzed samples for PFOA by UPLC-MS against a calibration curve of authentic standards prepared in laboratory reagent solvents following our laboratory quality assurance project plan (QAPP)[4], which generally follows EPA Method 537. ORD originally reported PFOA concentrations expressed as

[4] U.S. EPA National Exposure Research Laboratory, Quality Assurance Project Plan: Targeted Analyses of Per- and Polyfluoroalkyl Substances (PFAS) in Liquids Samples. D-EMMD-0031917-QP-1-0, 06May2019.

"ng/mL of sample in the vial" in WV DAQ Report #1[1] since the original sample volumes were not known. ORD did not determine sample recovery.

Quantitation of HFPO-DA

Test America and ORD estimated the concentration of HFPO-DA based on external standard calibration which uses the MS response for a stable isotope-labeled compound of known concentrations injected into the sample prior to analysis to serve as a surrogate standard.

Test America Denver prepared and analyzed the samples for HFPO-DA concentrations following SW-846 Method 8327A. Test America applied surrogate standards, quantitated based on their external calibration curve of Perfluoro(2-Propooxypionic acid) [HFPO-DA] and used a $^{13}C_3$-labeled isotope dilution internal standard to determine sample recovery. Sample recoveries for HFPO-DA were outside the acceptance criteria of ±30% in a subset of inlet sample batches collected primarily at the PTFE scrubber. Test America reported sample mass as ng/sample or µg/sample.

ORD similarly quantitated HFPO-DA using external standard based on native HFPO-DA purchased from Wellington Laboratories, Guelph, Ontario, Canada. A modified EPA method 533 was used by ORD. ORD originally reported PFOA concentrations expressed as "ng/mL of sample"[2]. ORD did not perform the analysis required to report sample recovery.

Additional Laboratory Considerations

Dilution. It is standard laboratory practice to dilute and reprocess a sample when an analytical result exceeds the calibration range established with the standards. Concentrations of HFPO-DA were particularly high in many of the inlet samples and both laboratories diluted samples as needed. The two laboratories worked within different calibration ranges leading to differences in which samples were diluted and by how much. Dilution is accounted for in the final concentration. Dilution involves tradeoffs: the additional dilution may yield more confidence as results fall within the calibrated range, but also may introduce more uncertainty due to the additional manipulation of the sample especially when using high dilution factors.

Test America's upper calibration limit for HFPO-DA was relatively low (<250 µg/L) compared to what was ultimately measured in the samples resulting in significantly greater dilution than used by ORD. Test America applied two dilutions to very high concentration samples, ultimately achieving dilution factors ranging from 500 to 2,500x. Test America's report provides results for the first and second dilution. It is recommended using the final concentrations (i.e., the number not in parentheses) when both are presented. Both first and second dilution values reported by Test America are provided in Appendix A. ORD established a higher upper calibration limit (<10,000 µg/L) that resulted in dilution factors ranging from 10 to 200x.

Sample Holding Time. The Test America laboratories received and generally completed all analyses within a six-week window following sample collection. ORD received sample extracts prepared by Test America between 5 to 8 months after sample collection and did not complete all analyses until more than a year after the original emissions testing dates.

Comparison of Laboratory Analytical Results

ORD provided targeted analysis results for concentrations of PFOA and HFPO-DA expressed as ng/ml of sample in the vial in WV DAQ Data Report #1[2]. ORD required additional information regarding

original sample volumes to convert concentrations to mass per sample as needed for emissions calculations and to directly compare with Test America results. This information was not available or could not be reliably interpreted from the Test America analytical testing information that was initially provided. Test America responded to our requests by providing complete lab reports and technical assistance in interpreting them.

The sample mass of PFOA and HFPO-DA expressed in µg/sample determined by ORD and Test America are provided for the PTFE scrubber in Table 2, the PFA scrubber in Table 3 and the FEP scrubber in Table 4. As a visual reference, a "heat map" is superimposed on the sample mass where the gradations in color reflect the range of concentrations within each data column. The heat maps help to highlight an analyte's presence in low (greens), medium (yellow and light oranges), and high concentrations (dark oranges and reds).

General Laboratory Comparison. The laboratories generally agree on the relative amount and distribution of both PFOA and HFPO-DA within each scrubber location/fraction. Sample mass is much greater in inlet fractions than outlets, and particularly within the impinger sample fraction (Tables 2-4). PFAS are present in outlet sample fractions but at much lower amounts. PFOA was generally not present in the outlet XAD fraction indicating no breakthrough. There are relatively small amounts of HFPO-DA present in the outlet impingers and XAD fraction.

Table 2. Concentrations of PFOA and HFPO-DA in MM0010 Train Samples Collected at the PTFE Scrubber. Uncolored cells equal to 0 is no peak area detected.

				PFOA		HFPO-DA	
				ORD	Test America	ORD	Test America
Location	MM010 Fraction	Run	Sample ID	µg/sample	µg/sample	µg/ sample	µg/ sample
PTFE Inlet	FH filter fraction composite	Run 1	12505-1	0.027	0.036	158	60.9
		Run2	12505-5	0.105	0.093	362	138
		Run3	12505-9	0.058	0.051	285	101
	BH filter fraction composite	Run 1	12505-2	0.580	1.66	14,065	13,636
		Run2	12505-6	1.17	1.71	12,269	9,093
		Run3	12505-10	1.83	2.68	30,065	24,035
	Impinger condensate	Run 1	12505-3	0.315	5.38	5,359	58,200
		Run2	12505-7	0.300	5.79	3,368	51,100
		Run3	12505-11	0.375	6.35	4,431	63,900
	XAD-2 resin tube	Run 1	12505-4	0.070	0.252	3,435	2,450
		Run2	12505-8	0.086	0.218	1,815	1,776
		Run3	12505-12	0.229	0.312	3,440	2,736
PTFE Outlet	FH filter fraction composite	Run 1	12503-1	0.257	0.201	222	88.2
		Run2	12503-5	0.362	0.265	312	123
		Run3	12503-9	0.320	0.193	308	113
	BH filter fraction composite	Run 1	12503-2	0.267	0.167	59.3	8.31
		Run2	12503-6	0.068	0.154	50.3	7.62
		Run3	12503-10	0.161	0.190	41.1	5.35
	Impinger condensate	Run 1	12503-3	0	0.046	0	1.09
		Run2	12503-7	0	0.016	0	0.837
		Run3	12503-11	0	0.023	0	1.87
	XAD-2 resin tube	Run 1	12503-4	0	0	25.7	0.158
		Run2	12503-8	0	0	0	0
		Run3	12503-12	0	0	0	0

Table 3. Concentrations of PFOA and HFPO-DA in MM0010 Train Samples Collected at the PFA Scrubber. Uncolored cells equal to 0 is no peak area detected.

				PFOA		HFPO-DA	
				ORD	Test America	ORD	Test America
Location	MM010 Fraction	Run	Sample ID	µg/sample	µg/sample	µg/ sample	µg/ sample
PFA Scrubber Inlet	FH filter fraction composite	Run 1	13273-1	0.145	0	47.9	24.4
		Run2	13273-5	0.333	0.242	113	50.1
		Run3	13273-9	0.202	0.179	75.0	14.7
	BH filter fraction composite	Run 1	13273-2	30.8	116	7,321	7,942
		Run2	13273-6	15.7	115	1,690	14,698
		Run3	13273-10	46.1	79.3	7,495	5,440
	Impinger condensate	Run 1	13273-3	315	480	140,807	307,000
		Run2	13273-7	343	476	223,166	457,000
		Run3	13273-11	347	495	139,070	276,000
	XAD-2 resin tube	Run 1	13273-4	0.201	0.259	325	61.6
		Run2	13273-8	0.202	0.332	592	211
		Run3	13273-12	0.147	0.220	210	23.4
PFA Scrubber Outlet	FH filter fraction composite	Run 1	13274-1	0	1.38	172	69.4
		Run2	13274-5	1.89	1.25	280	129
		Run3	13274-9	1.68	1.03	193	94.3
	BH filter fraction composite	Run 1	13274-2	2.03	2.43	1,826	2,220
		Run2	13274-6	1.37	2.37	1,695	2,110
		Run3	13274-10	1.70	3.13	4,577	2,700
	Impinger condensate	Run 1	13274-3	0	0	6.84	12.1
		Run2	13274-7	0	0	0	2.81
		Run3	13274-11	0	0	4.21	4.28
	XAD-2 resin tube	Run 1	13274-4	0	0	0	0.168
		Run2	13274-8	0	0	0	0.475
		Run3	13274-12	0	0	0	0.749

Table 4. Concentrations of PFOA and HFPO-DA in MM0010 Train Samples collected at the FEP Scrubber. Uncolored cells equal to 0 is no analyte detected.

				PFOA		HFPO-DA	
				ORD	Test America	ORD	Test America
Location	MM010 Fraction	Run	Sample ID	µg/sample	µg/sample	µg/ sample	µg/ sample
FEP Line 2 Inlet	FH filter fraction composite	Run 1	13312-1	1.43	1.80	2,536	1,040
		Run2	13312-5	0.601	0.522	783	394
		Run3	13312-9	1.10	0.831	668	286
	BH filter fraction composite	Run 1	13312-2	7.41	9.48	3,758	1,850
		Run2	13312-6	2.36	7.37	2,329	1,540
		Run3	13312-10	4.59	12.5	5,129	2,950
	Impinger condensate	Run 1	13312-3	48.8	102	39,534	103,000
		Run2	13312-7	50.9	110	28,904	91,000
		Run3	13312-11	51.8	115	41,279	95,200
	XAD-2 resin tube	Run 1	13312-4	0	0.035	0	5.21
		Run2	13312-8	0.013	0.208	53.5	20.3
		Run3	13312-12	0	0.213	72.8	55.2
FEP Line 3 Inlet	FH filter fraction composite	Run 1	13315-1	2.11	1.71	1,498	1,897
		Run2	13315-5	1.95	1.50	648	896
		Run3	13315-9	3.60	2.70	1,730	1,834
	BH filter fraction composite	Run 1	13315-2	11.1	11.7	4,158	2,210
		Run2	13315-6	17.7	13.9	1,975	3,143
		Run3	13315-10	12.2	12.6	1,551	1,739
	Impinger condensate	Run 1	13315-3	59.612	129	51,238	155,000
		Run2	13315-7	43.232	85.7	33,616	92,900
		Run3	13315-11	52.081	109	43,610	118,000
	XAD-2 resin tube	Run 1	13315-4	0.144	0.218	36.4	25.7
		Run2	13315-8	0.009	0.078	13.7	19.3
		Run3	13315-12	0.014	0.076	7.83	10.4
FEP Scrubber Outlet	FH filter fraction composite	Run 1	13316-1	0.502	0.315	19.6	9.90
		Run2	13316-5	0.451	0.330	7.35	5.07
		Run3	13316-9	0.483	0.360	8.88	7.39
	BH filter fraction composite	Run 1	13316-2	0.330	0.562	81.1	40.3
		Run2	13316-6	0.240	0.317	13.9	6.01
		Run3	13316-10	0.079	0.413	18.5	13.2
	Impinger condensate	Run 1	13316-3	0	0	0	3.05
		Run2	13316-7	0	0	0	0.794
		Run3	13316-11	0	0	0	2.73
	XAD-2 resin tube	Run 1	13316-4	0	0	13.3	0.121
		Run2	13316-8	0	0	0	0.048
		Run3	13316-12	0	0	7.52	0.043

Sample-to-Sample Laboratory Comparison. While there is generally agreement between laboratories, we note that on a sample by sample basis, there are some significant differences in both HFPO-DA and PFOA between laboratories in some of the high concentration inlet impinger samples.

We compared laboratory results on an individual sample basis using the Relative Percent Difference (RPD) as a measure of reproducibility between labs. RPD is calculated as the absolute value of the difference between samples divided by the mean of the two sample results:

$$\text{Relative \% Difference (RPD)} = \frac{ABS(X_2 - X_1)}{((X_2 + X_1)/2))} \text{ x } 100$$

Where X_1 is the Test America sample value and X_2 is the ORD sample value.

We feel that an RPD <50% is a respectable level of repeatability for this unstructured intra-laboratory comparison.

HFPO-DA sample masses are compared graphically in Figure 1 where ORD's value (Y-axis) for each sample is plotted relative to Test America's (X-axis). Note that the scales are logarithmic to cover the wide range of analyte mass in the samples. Figure 1 includes the 1:1 correspondence line indicating perfect agreement of laboratory results. Samples with good agreement between labs should plot near the 1:1 correspondence line across the full range of concentrations and fall within the 50% RPD envelope (dashed lines). The distribution of RPD for all HFPO-DA samples is shown as a box and whisker plot in Figure 2. Values less than the limit of quantitation for either laboratory are not compared. HFPO-DA RPD calculations compare ORD and Test America first dilution concentrations unless otherwise stated.

The relative relationship between laboratory results is generally consistent through the range of HPFO-DA. Of the comparisons where both results are greater than the limit of quantitation, 38% either fall within the 50% RPD range (Figure 1) or agree on non-detect. The median RPD for HFPO-DA of all samples is 66% (Figure 2). The median RPD is elevated by notably higher disagreement between labs in the impinger samples. ORD results tend to be biased somewhat higher than Test America in the lower concentration samples (<100 µg/sample), especially in the front half filter samples. Dilution appears to also introduce some bias in the high concentration samples, especially in the impinger samples that were highly diluted. For example, the sample mass of impinger sets that were highly diluted by Test America strongly disagree with ORD results in most of the inlet samples. ORD results tended to be much closer to Test America's first dilution results. For example, the median RPD comparison from the 1st dilution impinger data was 20% in contrast to 91% in the 2nd dilution.

PFOA samples are compared in Figure 3 and RPD distribution characteristics among MM-0010 fractions are provided in Figure 4. PFOA was present in much lower mass and was less than the limit of quantitation or not detected in one or both of the laboratories in a number of samples. There were 15 non-detects in Test America samples (a value of 0 in Tables 2-4) that were also non-detects in ORD data. The RPD of PFOA samples was generally within the 50% range. The median RPD of 45 valid comparisons (both samples > LOQ) was 41%. Any effect on laboratory agreement are less for PFOA as fewer samples were diluted and the dilution factors were lower due to the generally low concentrations in the samples. Whether the extensive holding time prior to ORD analysis resulted in sample degradation or influenced ORD results is unknown.

Laboratory Comparison Conclusions. Test America is a certified laboratory that first received, prepared, and analyzed the MM0100 samples collected at the Chemours Washington Works facility within holding times, and prepared all extracts used by ORD. We conclude that the ORD laboratory results for HFPO-DA and PFOA are within acceptable agreement levels with and support the sample results provided by Test America. Some differences between laboratory mass estimates should be expected and reflect the factors related to laboratory processing as discussed. Test America results will be used in the next section for emission calculations.

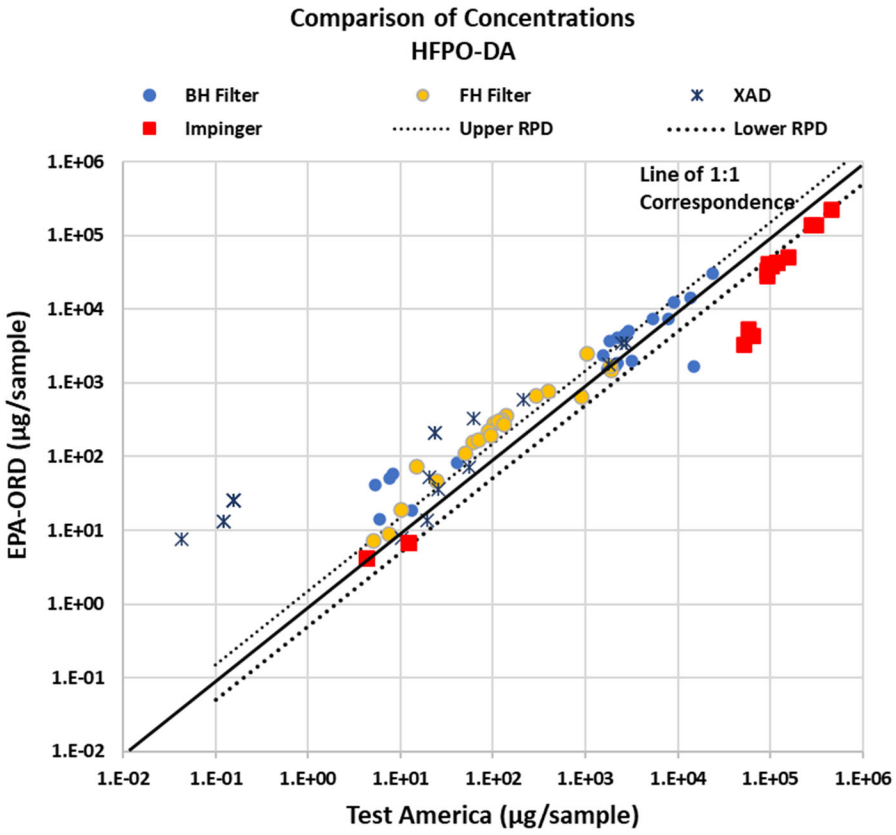

Figure 1. Comparison of HFPO-DA sample mass determined by analytical laboratories from all locations, identified by MM0010 fraction. Note that both 1-dilution and 2-dilutionTest America results are shown for the impinger fraction.

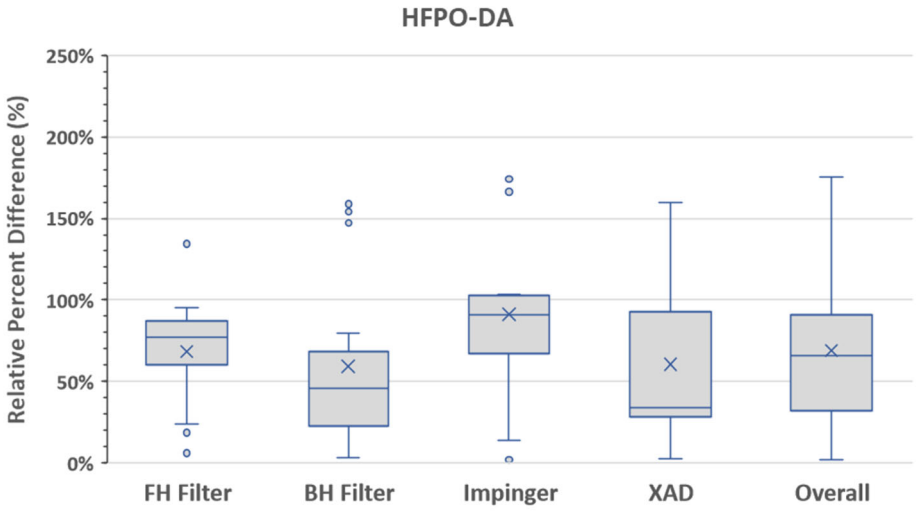

Figure 2. Box and whiskers plot of distribution of relative percent difference of HFPO-DA in samples processed by ORD and Test America. The population mean is indicated by X and quartiles by lines. Test America data was as reported using final diluted value.

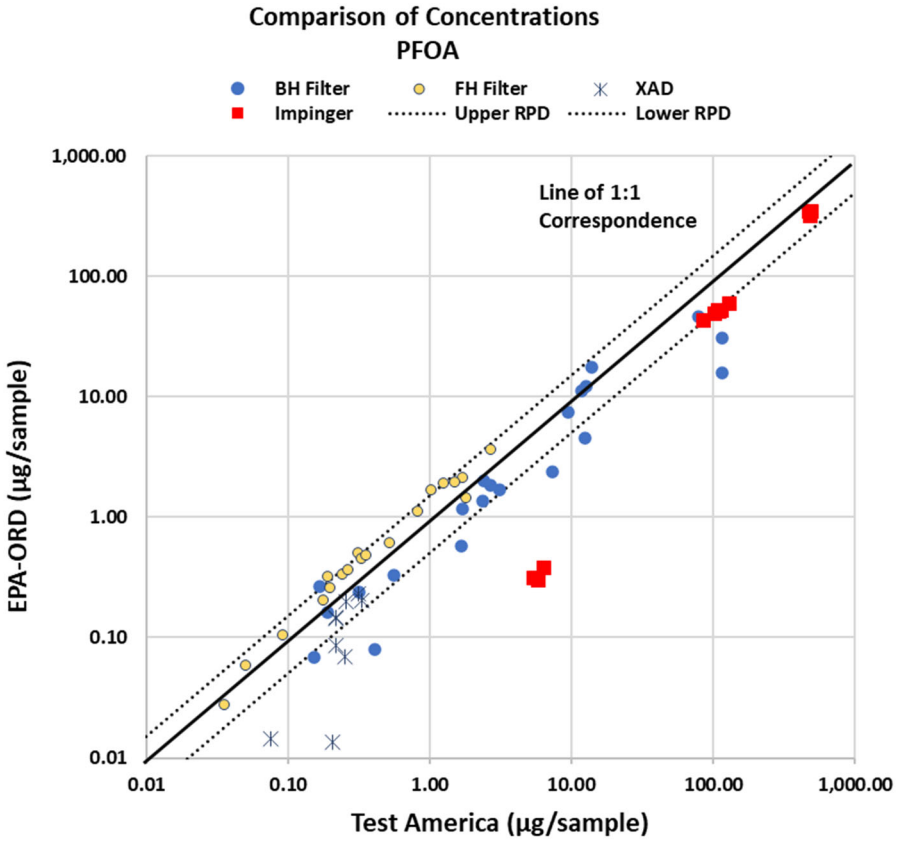

Figure 3. Comparison of PFOA sample mass determined by analytical laboratories from all locations, identified by MM0010 fraction.

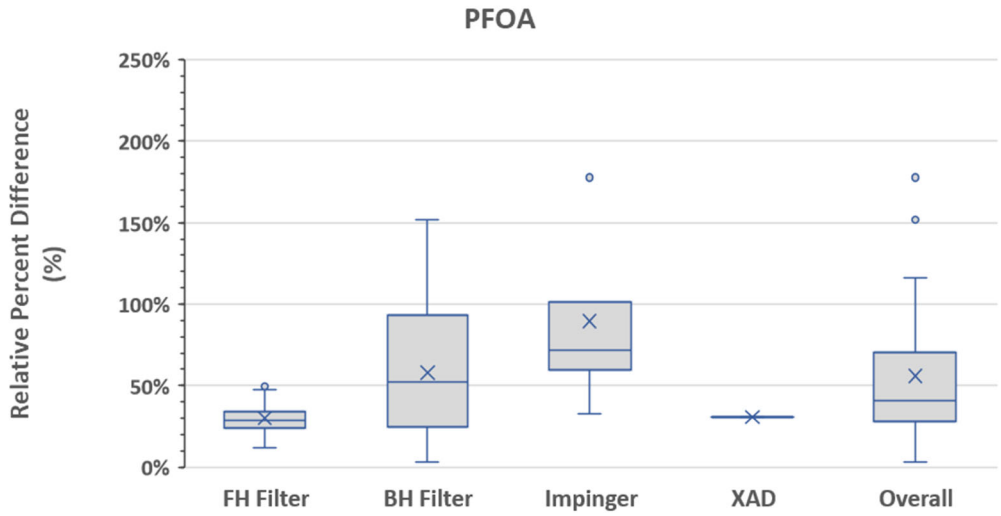

Figure 4. Box and whiskers plot of distribution of relative percent difference of PFOA in samples processed by ORD and Test America. The population mean is indicated by X and quartiles by lines.

Emissions Estimates

OBG conducted the MM-0010 emission tests and provided Chemours with a report containing emission calculations. ORD was provided tables from that report that include critical test data and estimated emission concentrations. The OBG reference material also contained examples for some of the calculations used to derive emission and scrubber removal efficiency.

ORD independently calculated the emission estimates at the 3 scrubber locations. Emissions calculations utilizing Test America analytical results are provided for the PTFE scrubber in Appendix B, for the PFA scrubber in Appendix C, and for the FEP scrubber in Appendix D. Note that our calculation tables differ in organization from those provided by OBG in an effort to improve clarity and to account for intermediate calculation steps.

Emissions Calculations Method

Here we briefly summarize our process for estimating emissions. Below we describe the calculation steps in metric units, although the appendices carry out the calculations in both English and metric units.

Each sample processed in the laboratory represents the mass of sample collected during the 180-minute air sampling test in the MM-0010 fraction and is expressed as µg/sample. The mass in each sample fraction as determined by Test America is provided in Tables 2-4 as well as the appendices. The Total Sample Mass for each test run is the sum of the four fractions.

Total Sample Mass (µg/sample) = Front Half Filter + Back Half Filter + Impinger Condensate + XAD

It is necessary to know the total volume of gas sampled during the time of the test, as well as the ongoing rate of air flow through the pipe or stack that the test represents to determine emissions. The flow of air through the stack or pipe is measured as volume per unit time. It is standard practice to convert the actual air flow to a dry gas at standard conditions by adjusting for temperature, water content, pressure, and carbon dioxide content. The converted dry gas volumes during the test and

ongoing rate of air flow through the stack or pipe are provided in the OBG tables (Tables B-3, C-3, and D-3). We note that there was insufficient information to calculate dry gas conditions from the information provided. We accept that OBG correctly determined dry standard gas volumes from actual measured air volumes and utilize their dry gas air volumes provided in their report tables to complete the emissions calculation in the Appendices.

To determine the emission of a compound from the facility, the total sample mass collected during the test must be converted to a concentration in air emissions based on the volume of air sampled during the 180 minutes of sample collection.

$$\textit{Analyte Concentration in Air Flow } (\mu g/m^3) = \frac{\textit{Total Sample Mass } (\mu g/sample)}{\textit{Volume Air Collected During Sample } (m3)}$$

This concentration is then used to determine the rate of mass moving through the pipe or stack in a specified period of time by multiplying the sample concentration by the volume of air flowing through the pipe or stack based on its cross-sectional area and the air velocity.

$$\textit{Emission Rate } (\mu g/\text{unit time}) = \textit{Analyte Concentration } (\mu g/m^3) \textit{ x Volumetric Air Flow } (m^3/\text{unit time})$$

The air flow rate is reported in volume per minute. To convert to an hourly basis, multiply by 60.

The Removal Efficiency expressed in percent of mass per unit time is the measured emission at the scrubber outlet relative to that observed at the scrubber inlet.

$$\textit{Removal Efficiency \%} = \frac{\textit{Inlet Emission Rate} - \textit{Outlet Emission Rate}}{\textit{Inlet Emission Rate}} \textit{ x 100}$$

Each Appendix (B, C, and D) contains the data for sample mass using Test America data, the ORD emissions calculation table, and the OBG emissions report table for the inlet and outlet for each scrubber.

Emission Results

Table 5 summarizes the emissions estimates calculated with Test America data as provided by OBG and as independently computed by ORD. ORD emissions estimates and removal rates are the same or within fractions of a percent of those reported by OBG. There are minor differences between estimates reflecting rounding choices applied during the series of calculations. We note, however, that ORD calculates a higher removal percentage for PFOA at the FEP scrubber than reported in the OBG table, which is hypothesized to be a typographical error by OBG.

Table 5. Summary of PFAS mass at inflow and outflow of scrubbers and removal efficiency as calculated by ORD using Test America compared to OBG reported emissions.

		ORD Calculations from Test America Data				OBG Tables	
		PFOA lb/hr	HFPO-DA lb/hr			PFOA lb/hr	HFPO-DA lb/hr
PTFE Scrubber	Net In	4.66E-04	4.32	PTFE Scrubber	Net In	4.67E-04	4.32
	Net Out	3.14E-05	0.009		Net Out	3.14E-05	0.009
	Removal	93.3%	99.8%		Removal	93.3%	99.8%
PFA Scrubber	Net In	6.78E-04	0.411	PFA Scrubber	Net In	6.78E-04	0.409
	Net Out	7.18E-06	0.0044		Net Out	7.19E-06	0.0044
	Removal	98.9%	98.9%		Removal	98.9%	98.9%
FEP Scrubber	Net In	2.94E-04	0.282	FEP Scrubber	Net In	2.93E-04	0.282
	Net Out	3.12E-06	0.0001		Net Out	3.12E-06	0.0001
	Removal	98.9%	100.0%		Removal	96.9%	99.9%

Finally, we estimated the annual emissions of PFOA and HFPO-DA from the 3 scrubber locations based on the hourly emission rates determined during the emissions testing as shown in Table 6. This computation assumes that the facility continuously operates at the same conditions as monitored during the emissions tests for the entire year (24 hours x 365 days).

Table 6. Annual Release of PFOA and HFPO-DA to Air from the 3 scrubber locations at the Chemours Washington Works Facility.

	Annual Release to Air	
	PFOA	HFPO-DA
	lbs	lbs
PTFE	0.27	76.5
PFA	0.06	38.4
FEP	0.03	1.1

We noted in the laboratory comparison that while sample results are generally very similar between Test America and ORD, there are also differences within specific location/fraction data sets that appear to primarily stem from dilution practices employed at each laboratory. We have observed that differences in inlet impinger fraction are particularly notable. We have carried out the emission calculations for all three data sets (Test America 1 and 2 dilution and ORD) to determine the impact of analytical differences on the removal efficiency in Figure 5. Although some of the differences between laboratory sample results were relatively large in some of the inlet samples, they have little impact on the final removal efficiencies as there are only small differences in the amount of the compounds in the outlet samples. Removal efficiency remained greater than 97% regardless of sample results used.

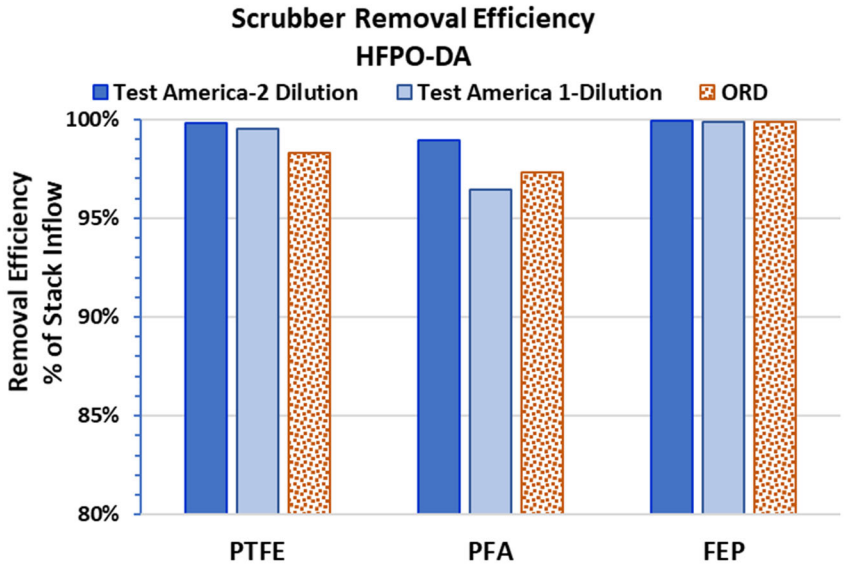

Figure 5. Scrubber removal efficiency for HFPO-DA using various data sets, including Test-America 2-dilution, Test-America 1-dilution and ORD results.

Summary

- Quantitative laboratory results are consistent between Test America and ORD at an acceptable level for an unstructured intra-laboratory comparison.

- Emissions calculations based on Test America data are consistent with results presented by OBG.

- Extrapolating laboratory results for sample mass in MM-0010 test samples to rate of chemical emissions at the scrubber location resulted in the same removal efficiencies, (93% to nearly 100%).

- Removal efficiencies are not sensitive to differences in sample results between laboratories.

- As reported in WV DAQ Report #2[3], we identified similar patterns in the relative abundances for many of the additional PFAS analytes identified in non-targeted analysis with regards to scrubber inlets and outlets as were quantified for HFPO-DA and PFOA. However, removal efficiencies could not be determined due to the qualitative nature of non-targeted analyses.

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Appendix A

Laboratory Results for PFOA and HFPO-DA as Reported by EPA-ORD and Test America Laboratories

Sample Mass Data Table Notes

- Sample mass data tables are provided for PFOA and HFPO-DA in MM0010 Train Sample mass is reported in µg/sample. Data include quality assurance flags as applied by each laboratory.
- Test America's column includes two results for some samples. The first number is the final reported µg/sample. If a second dilution was performed, the number in parenthesis is the first dilution result, flagged as exceeding the calibration range "e".
- "u" flags samples below ORD's reporting limit, equal to < Limit of Quantitation (LOQ).
- "J" flags samples below Test America's reporting limit, equal to < Limit of Quantitation (LOQ).
- "JC1" flags ORD values that exceeded the calibration range.
- "e" flags Test America's values that exceeded the calibration range.
- ND is no peak area detected.

				PFOA		HFPO-DA	
				ORD	Test America	ORD	Test America
Location	MM010 Fraction	Run	Sample ID	µg/sample	µg/sample	µg/ sample	µg/ sample
PTFE Inlet	FH filter fraction composite	Run 1	12505-1	0.027 (u)	0.036	158	60.9
		Run2	12505-5	0.105 (u)	0.093	362	138
		Run3	12505-9	0.058 (u)	0.051	285	101
	BH filter fraction composite	Run 1	12505-2	0.580	1.660	14,065 (JC1)	13,636 (11,400e)
		Run2	12505-6	1.17	1.710	12,269 (JC1)	9,093 (9,540e)
		Run3	12505-10	1.83	2.680	30,065 (JC1)	24,035 (15,600e)
	Impinger condensate	Run 1	12505-3	0.32	5.380	5,359	58,200 (5,380e)
		Run2	12505-7	0.300	5.790	3,368	51,100 (5,390e)
		Run3	12505-11	0.375	6.350	4,431	63,900 (6,060e)
	XAD-2 resin tube	Run 1	12505-4	.0.070 (u)	0.252	3,435	2,450 (2,960e)
		Run2	12505-8	0.086 (u)	0.218	1,815	1,776 (2,130e)
		Run3	12505-12	0.229	0.312	3,440	2,736 (3,020e)
PTFE Outlet	FH filter fraction composite	Run 1	12503-1	0.257	0.201	222	88.2
		Run2	12503-5	0.362	0.265	312	123
		Run3	12503-9	0.320	0.193	308	113
	BH filter fraction composite	Run 1	12503-2	0.267 (u)	0.167	59.3	8.31
		Run2	12503-6	0.068 (u)	0.154	50.3	7.62
		Run3	12503-10	0.161 (u)	0.190	41.1	5.35
	Impinger condensate	Run 1	12503-3	ND	0.046	ND	1.09
		Run2	12503-7	ND	0.016	ND	0.837
		Run3	12503-11	ND	0.023	ND	1.87
	XAD-2 resin tube	Run 1	12503-4	ND	ND	25.7	0.158 (u)
		Run2	12503-8	ND	ND	ND	ND
		Run3	12503-12	ND	ND	ND	ND
PFA Scrubber Inlet	FH filter fraction composite	Run 1	13273-1	0.145 (u)	ND	47.9	24.4
		Run2	13273-5	0.333	0.242	113	50.0
		Run3	13273-9	0.202	0.179	75	14.7
	BH filter fraction composite	Run 1	13273-2	30.8	116	7,321	7,942 (9,760e)
		Run2	13273-6	15.7 (JC1)	115	1,690	14,698 (12,600e)
		Run3	13273-10	46.1	79.3	7,495	5,440 (7,370e)

				PFOA		HFPO-DA	
				ORD	Test America	ORD	Test America
Location	MM010 Fraction	Run	Sample ID	µg/sample	µg/sample	µg/ sample	µg/ sample
PFA Scrubber Inlet	Impinger condensate	Run 1	13273-3	315 (JC1)	480	140,807	307,000 (106,000e)
		Run2	13273-7	343 (JC1)	476	223,166	457,000 (133,000e)
		Run3	13273-11	347 (JC1)	495	139,070	276,000 (87,200e)
	XAD-2 resin tube	Run 1	13273-4	0.201 (u)	0.259	325	61.6
		Run2	13273-8	0.202 (u)	0.332	592	211
		Run3	13273-12	0.0147 (U)	0.220	210	23.4
PFA Scrubber Outlet	FH filter fraction composite	Run 1	13274-1	ND	1.38	172	74.0
		Run2	13274-5	1.89	1.25	280	151
		Run3	13274-9	1.68	1.03	193	102
	BH filter fraction composite	Run 1	13274-2	2.03	2.43	1,826	2,220
		Run2	13274-6	1.37	2.37	1,695	1,814 (2,580e)
		Run3	13274-10	1.70	3.13	4,577	2,700
	Impinger condensate	Run 1	13274-3	ND	ND	6.84	12.1
		Run2	13274-7	ND	ND	ND	2.81
		Run3	13274-11	ND	ND	4.21	4.28
	XAD-2 resin tube	Run 1	13274-4	ND	ND	ND	0.168 (u)
		Run2	13274-8	ND	ND	ND	0.475
		Run3	13274-12	ND	ND	ND	0.749
FEP Line 2 Inlet	FH filter fraction composite	Run 1	13312-1	1.43	1.8	2,536	1,040
		Run2	13312-5	0.601	0.522	783	394
		Run3	13312-9	1.10	0.831	668	286
	BH filter fraction composite	Run 1	13312-2	7.41	9.480	3,758	1,850
		Run2	13312-6	2.36	7.37	2,329	1,540
		Run3	13312-10	4.59	12.5	5,129	2,950
	Impinger condensate	Run 1	13312-3	48.8	102	39,534	103,000 (36,700e)
		Run2	13312-7	50.9	110	28,904	91,000 (36,400e)
		Run3	13312-11	51.8	115	41,279	95,200 (36,000e)

				PFOA		HFPO-DA	
				ORD	Test America	ORD	Test America
Location	MM010 Fraction	Run	Sample ID	µg/sample	µg/sample	µg/ sample	µg/ sample
FEP Line 2 Inlet	XAD-2 resin tube	Run 1	13312-4	ND	0.035	ND	5.21
		Run2	13312-8	0.013 (u)	0.208	53.5	20.3
		Run3	13312-12	ND	0.213	72.8	55.2
FEP Line 3 Inlet	FH filter fraction composite	Run 1	13315-1	2.11	1.71	1,498	1,897 (1,710e)
		Run2	13315-5	1.95	1.50	648	896
		Run3	13315-9	3.60	2.70	1,834	1,834 (1,6800e)
	BH filter fraction composite	Run 1	13315-2	11.1	11.7	4,158	2,210
		Run2	13315-6	17.7	13.9	1,975	3,143 (3,760e)
		Run3	13315-10	12.2	12.6	1,551	1,739 (2,310e)
	Impinger condensate	Run 1	13315-3	59.6	129	51,238	155,000 (43,500e)
		Run2	13315-7	43.2	85.7	33,616	92,900 (35,200e)
		Run3	13315-11	52.1	109	43,610	118,000 (36,700e)
	XAD-2 resin tube	Run 1	13315-4	0.144 (u)	0.218	36.4	25.7
		Run2	13315-8	.0.009 (u)	0.078	13.7	19.3
		Run3	13315-12	0.014 (u)	0.076	7.8	10.4
FEP Scrubber Outlet	FH filter fraction composite	Run 1	13316-1	0.502	0.315	19.6	9.9
		Run2	13316-5	0.451	0.330	7.35	5.07
		Run3	13316-9	0.483	0.360	8.88	7.39
	BH filter fraction composite	Run 1	13316-2	0.330	0.562	81.1	40.3
		Run2	13316-6	0.024 (u)	0.317	13.9	6.01
		Run3	13316-10	0.079 (u)	0.413	18.5	13.2
	Impinger condensate	Run 1	13316-3	ND	ND	ND	3.05
		Run2	13316-7	ND	ND	ND	0.794
		Run3	13316-11	ND	ND	ND	2.73
	XAD-2 resin tube	Run 1	13316-4	ND	ND	13.3	0.121 (u)
		Run2	13316-8	ND	ND	ND	0.048 (u)
		Run3	13316-12	ND	ND	7.5	0.043 (u)

Appendix B

Emissions Estimates from PTFE Scrubber Inlet and Outlet Chemours Facility in Parkersburg West, Virginia

Sampled August 24, 2018

Table B-1. S*ample Mass For HFPO-DA and PFOA at the PTFE Location Based on Test America Analytical Results*

HFPO-DA

MASS per sample (µg/sample)

Location	Run	FH	BH	Impinger	XAD	Total Sample Mass
PFTE Inlet	Run 1	60.9	13,636	58,200	2,450	74,347
	Run2	138	9,093	51,100	1,776	62,107
	Run3	101	24,035	63,900	2,736	90,772
	Average	100	15,588	57,733	2,321	75,742
PTFE Outlet	Run 1	88.2	8.31	1.09	0.2	97.8
	Run2	123	7.62	0.84	0.0	131
	Run3	113	5.35	1.87	0.0	120
	Average	108	7.09	1.27	0.1	116

PFOA

MASS per sample (µg/sample)

Location	Run	FH	BH	Impinger	XAD	Total Sample Mass
PFTE Inlet	Run 1	0.036	1.66	5.38	0.252	7.33
	Run2	0.093	1.71	5.79	0.218	7.81
	Run3	0.051	2.68	6.35	0.312	9.39
	Average	0.060	2.02	5.84	0.261	8.18
PTFE Outlet	Run 1	0.201	0.167	0.046	0.0	0.414
	Run2	0.265	0.154	0.016	0.0	0.435
	Run3	0.193	0.190	0.023	0.0	0.406
	Average	0.220	0.170	0.028	0.0	0.418

Table B-2. *Emission estimate for HFPO-DA and PFOA at the PTFE Scrubber*

	PTFE							
	PTFE Scrubber Inlet				PTFE Scrubber Outlet			
	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Air Flow, as dry gas standard								
Collected Air Sample Volume During Test, expressed in ft^3 (dscf, ***Table B-3 OBG line 7***)	51.694	51.879	50.097	**51.223**	46.82	43.995	45.061	45.292
Collected Air Sample Volume During Test, expressed in m^3	1.464	1.469	1.419	1.451	1.326	1.246	1.276	1.283
Volumetric flow rate through pipe, expressed in ft^3/minute (dscfm, ***Table B-3 OBG line 10***)	22,125	22,194	21,882	22,067	26,441	24,850	25,694	25,662
Volumetric Air flow rate, expressed in m^3/minute	627	628	620	625	749	704	728	727
Analyte Concentration in Gas Volume Collected During Test								
HFPO-DA								
HFPO-DA Total Mass Measured in Samples				HFPO-DA				
HFPO-Da total mass measured in sample, µg/sample (***Table B-1***)	**74,347**	**62,107**	**90,772**	**75,742**	**98**	**131**	**120**	**116**
HFPO-DA total mass measured in sample, mg/sample	74.347	62.107	90.772	75.742	0.098	0.131	0.120	0.116
HFPO-DA total mass measured in sample, lbs/sample	1.64E-04	1.37E-04	2.00E-04	1.67E-04	2.16E-07	2.90E-07	2.65E-07	2.57E-07
HFPO-DA Concentration in Air = Total Mass ÷ Collected Air Sample Volume								
HFPO-DA Concentration (lb/ft^3)	3.17E-06	2.64E-06	4.00E-06	3.26E-06	4.60E-09	6.59E-09	5.88E-09	5.67E-09
HFPO-DA Concentration (mg/m^3)	5.08E+01	4.23E+01	6.40E+01	5.22E+01	7.37E-02	1.06E-01	9.42E-02	9.08E-02
PFOA								
PFOA Total Mass Measured in Samples				PFOA				
PFOA total mass measured in sample, µg/sample ***(Table B-1)***	**7.33**	**7.81**	**9.39**	**8.18**	**0.41**	**0.44**	**0.41**	**0.42**
PFOA total mass measured in sample, mg/sample	0.007	0.008	0.009	0.008	4.14E-04	4.35E-04	4.06E-04	4.18E-04
PFOA total mass measured in sample, lbs/sample	1.62E-08	1.72E-08	2.07E-08	1.80E-08	9.13E-10	9.60E-10	8.95E-10	9.22E-10
PFOA Concentration in Air =Total Mass ÷ Collected Air Sample Volume								
PFOA Concentration (lb/ft^3)	3.13E-10	3.32E-10	4.13E-10	3.52E-10	1.95E-11	2.18E-11	1.99E-11	2.04E-11
PFOA Concentration (mg/m^3)	5.01E-03	5.32E-03	6.62E-03	5.64E-03	3.12E-04	3.49E-04	3.18E-04	3.26E-04
HFPO-DA Emission Rate								
	HFPO-DA Produced at PTFE before Scrubber				HFPO-DA Released to Air from PTFE after Scrubber			
HFPO-DA Emissions Per Hour = HFPO-DA Concentration in Air x Volmetric Flow Rate x 60								
lbs/hr	4.21E+00	3.52E+00	5.25E+00	4.32E+00	7.30E-03	9.82E-03	9.07E-03	8.73E-03
kg/hr	1.91E+00	1.59E+00	2.38E+00	1.96E+00	3.31E-03	4.46E-03	4.11E-03	3.96E-03
HFPO-DA Emissions Per Year								
lbs/yr	36,878	30,793	45,951	37,816	63.98	86.05	79.45	76.48
kg/yr	16,725	13,965	20,839	17,150	29.02	39.03	36.03	34.69
HFPO-DA Removal Efficiency = (Inlet -Outlet Emission Rate) ÷ Inlet Emission Rate x 100	**99.8%**	**99.7%**	**99.8%**	**99.8%**				
PFOA Emission Rate								
PFOA Emissions per Hour = PFOA Concentration in Air x Volmetric Flow Rate x 60	PFOA Produced at PTFE before Scrubber				PFOA Released to Air from PTFE after Scrubber			
lbs/hr	4.15E-04	4.42E-04	5.43E-04	4.66E-04	3.09E-05	3.25E-05	3.06E-05	3.14E-05
kg/hr	1.88E-04	2.00E-04	2.46E-04	2.11E-04	1.40E-05	1.47E-05	1.39E-05	1.42E-05
PFOA Emissions Per Year								
lbs/yr	3.6	3.9	4.8	4.1	0.27	0.28	0.27	0.27
kg/yr	1.6	1.8	2.2	1.9	0.12	0.13	0.12	0.12
PFOA Removal Efficiency (%) = (Inlet -Outlet Emission Rate) ÷ Inlet Emission Rate x 100	**92.5%**	**92.6%**	**94.4%**	**93.3%**				

Table B-3. *OBG Engineering Report for the PTFE Scrubber*

Table 1
The Chemours Company - Washington Works
PTFE Scrubber Emissions
Parkersburg, West Virginia

Run Identification	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Run Date	24Aug18	24Aug18	24Aug18		24Aug18	24Aug18	24Aug18	
Start/Stop Time	0922-1022	1120-1220	1330-1430		0922-1025	1120-1220	1330-1430	
Source ID		Scrubber Inlet				Scrubber Outlet		
Exhaust Gas Conditions								
Temperature (deg. F)	245	250	245	**247**	115	115	116	**115**
Moisture (volume %)	4.1	4.0	4.2	**4.1**	7.3	7.9	7.6	**7.6**
Oxygen (dry volume %)	20.0	20.0	20.0	**20.0**	20.0	20.0	20.0	**20.0**
Carbon Dioxide (dry volume %)	0.10	0.10	0.10	**0.10**	0.10	0.10	0.10	**0.10**
Collected Sample Volume								
dscf	51.694	51.879	50.097	**51.223**	46.820	43.995	45.061	**45.292**
Volumetric Flow Rate								
acfm	30,394	30,733	30,096	**30,408**	30,765	29,078	29,993	**29,945**
dscfm	22,127	22,194	21,882	**22,068**	26,441	24,850	25,694	**25,662**
C3 Dimer Acid Emissions								
mg	74.35	62.11	90.67	**75.71**	0.10	0.13	0.12	**0.12**
mg/dscm	5.08E+01	4.23E+01	6.39E+01	**5.23E+01**	7.37E-02	1.06E-01	9.42E-02	**9.12E-02**
lb/hr	4.21E+00	3.51E+00	5.24E+00	**4.32E+00**	7.30E-03	9.82E-03	9.07E-03	**8.73E-03**
Removal Efficiency								
percent	**99.8**	**99.7**	**99.8**	**99.8**				
PFOA Emissions								
mg	0.00733	0.00781	0.00939	**0.00818**	0.000414	0.000435	0.000406	**0.000418**
mg/dscm	5.01E-03	5.32E-03	6.62E-03	**5.65E-03**	3.12E-04	3.49E-04	3.18E-04	**3.27E-04**
lb/hr	4.15E-04	4.42E-04	5.43E-04	**4.67E-04**	3.09E-05	3.25E-05	3.06E-05	**3.14E-05**
Removal Efficiency								
percent	**92.5**	**92.6**	**94.4**	**93.3**				

Appendix C

Emissions Estimates from PFA Scrubber Inlet and Outlet Chemours Facility in Parkersburg West, Virginia

Sampled November 6, 2018

Table C-1. S*ample Mass For HFPO-DA and PFOA at the PFA Location Based on Test America Analytical Results*

		HFPO-DA MASS per sample (µg/sample)						PFOA MASS per sample (µg/sample)					
Location	**Run**	**FH**	**BH**	**Impinger**	**XAD**	**Total Sample Mass**	**Location**	**Run**	**FH**	**BH**	**Impinger**	**XAD**	**Total Sample Mass**
PFA Inlet	Run 1	24.4	7,942	307,000	61.6	315,028	**PFA Inlet**	Run 1	0.0	116	480	0.259	596.26
	Run2	50.0	14,698	457,000	211	471,959		Run2	0.242	115	476	0.332	591.57
	Run3	14.7	5,440	276,000	23.4	281,478		Run3	0.179	79.3	495	0.220	574.70
	Average	29.7	9,360	346,667	98.7	356,155		Average	0.140	103.4	483.7	0.270	587.51
PFA Outlet	Run 1	74.0	2,220	12.10	0.2	2,306	**PFA Outlet**	Run 1	1.38	2.43	0.0	0.0	3.81
	Run2	151	1,814	2.81	0.5	1,968		Run2	1.25	2.37	0.0	0.0	3.62
	Run3	102	2,700	4.28	0.75	2,807		Run3	1.03	3.13	0.0	0.0	4.16
	Average	109	2,245	6.40	0.5	2,361		Average	1.22	2.64	0.0	0.0	3.86

Table C-2. *Emission estimate for HFPO-DA and PFOA at the PFA Scrubber*

	PFA							
	PFA Scrubber Inlet				PFA Scrubber Outlet			
	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Air Flow, as dry gas standard								
Collected Air Sample Volume During Test, expressed in ft^3 (dscf, ***Table C-3 OBG line 7***)	42.677	41.569	41.492	**41.913**	30.492	31.139	33.548	31.726
Collected Air Sample Volume During Test, expressed in m^3	1.209	1.177	1.175	1.187	0.863	0.882	0.950	0.898
Volumetric flow rate through pipe, expressed in ft^3/minute (dscfm, ***Table C-3 OBG line 10***)	372	354	370	365	441	417	479	446
Volumetric Air flow rate, expressed in m^3/minute	11	10	10	10	12	12	14	13
Analyte Concentration in Gas Volume Collected During Test								
HFPO-DA								
HFPO-DA Total Mass Measured in Samples					HFPO-DA			
HFPO-Da total mass measured in sample, µg/sample (***Table C-1***)	**315,028**	**471,959**	**281,478**	**356,155**	**2,306**	**1,968**	**2,807**	**2,361**
HFPO-DA total mass measured in sample, mg/sample	315.028	471.959	281.478	356.155	2.306	1.968	2.807	2.361
HFPO-DA total mass measured in sample, lbs/sample	6.95E-04	1.04E-03	6.21E-04	7.85E-04	5.09E-06	4.34E-06	6.19E-06	5.20E-06
HFPO-DA Concentration in Air = Total Mass ÷ Collected Air Sample Volume								
HFPO-DA Concentration (lb/ft^3)	1.63E-05	2.50E-05	1.50E-05	1.87E-05	1.67E-07	1.39E-07	1.84E-07	1.64E-07
HFPO-DA Concentration (mg/m^3)	2.61E+02	4.01E+02	2.40E+02	3.00E+02	2.67E+00	2.23E+00	2.95E+00	2.63E+00
PFOA								
PFOA Total Mass Measured in Samples					PFOA			
PFOA total mass measured in sample, µg/sample ***(Table C-1)***	**596**	**592**	**575**	**588**	**3.8**	**3.6**	**4.2**	**3.9**
PFOA total mass measured in sample, mg/sample	0.596	0.592	0.575	0.588	3.81E-03	3.62E-03	4.16E-03	3.86E-03
PFOA total mass measured in sample, lbs/sample	1.31E-06	1.30E-06	1.27E-06	1.30E-06	8.40E-09	7.98E-09	9.17E-09	8.52E-09
PFOA Concentration in Air =Total Mass ÷ Collected Air Sample Volume								
PFOA Concentration (lb/ft^3)	3.08E-08	3.14E-08	3.05E-08	3.09E-08	2.76E-10	2.56E-10	2.73E-10	2.68E-10
PFOA Concentration (mg/m^3)	4.93E-01	5.03E-01	4.89E-01	4.95E-01	4.41E-03	4.11E-03	4.38E-03	4.30E-03
HFPO-DA Emission Rate								
	HFPO-DA Produced at PFA before Scrubber				HFPO-DA Released to Air from PFA after Scrubber			
HFPO-DA Emissions Per Hour = HFPO-DA Concentration in Air x Volmetric Flow Rate x 60								
lbs/hr	3.63E-01	5.32E-01	3.32E-01	4.11E-01	4.41E-03	3.49E-03	5.30E-03	4.39E-03
kg/hr	1.65E-01	2.41E-01	1.51E-01	1.86E-01	2.00E-03	1.58E-03	2.40E-03	1.99E-03
HFPO-DA Emissions Per Year								
lbs/yr	3,182	4,658	2,909	3,598	38.66	30.55	46.45	38.43
kg/yr	1,443	2,112	1,319	1,632	17.53	13.85	21.07	17.43
HFPO-DA Removal Efficiency = (Inlet -Outlet Emission Rate) ÷ Inlet Emission Rate x 100	**98.8%**	**99.3%**	**98.4%**	**98.9%**				
PFOA Emission Rate								
PFOA Emissions per Hour = PFOA Concentration in Air x Volmetric Flow Rate x 60	PFOA Produced at PFA before Scrubber				PFOA Released to Air from PFA after Scrubber			
lbs/hr	6.88E-04	6.67E-04	6.78E-04	6.78E-04	7.29E-06	6.41E-06	7.86E-06	7.18E-06
kg/hr	3.12E-04	3.02E-04	3.07E-04	3.07E-04	3.31E-06	2.91E-06	3.56E-06	3.26E-06
PFOA Emissions Per Year								
lbs/yr	6.0	5.8	5.9	5.9	0.06	0.06	0.07	0.06
kg/yr	2.7	2.6	2.7	2.7	0.03	0.03	0.03	0.03
PFOA Removal Efficiency (%) = (Inlet -Outlet Emission Rate) ÷ Inlet Emission Rate x 100	**98.9%**	**99.0%**	**98.8%**	**98.9%**				

Table C-3. *OBG Engineering Report for the PFA Scrubber*

Table 2
The Chemours Company - Washington Works
PFA Scrubber Emissions
Parkersburg, West Virginia

Run Identification	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Run Date	06Nov18	06Nov18	06Nov18		06Nov18	06Nov18	06Nov18	
Start/Stop Time	1315-1415	1510-1610	1717-1817		1315-1415	1510-1610	1717-1817	
Source ID		Scrubber Inlet				Scrubber Outlet		
Exhaust Gas Conditions								
Temperature (deg. F)	279	277	282	**279**	68	69	63	**67**
Moisture (volume %)	49.6	50.8	47.6	**49.3**	1.3	1.7	2.4	**1.8**
Oxygen (dry volume %)	20.0	20.0	20.0	**20.0**	20.0	20.0	20.0	**20.0**
Carbon Dioxide (dry volume %)	0.10	0.10	0.10	**0.10**	0.10	0.10	0.10	**0.10**
Collected Sample Volume								
dscf	42.677	41.569	41.492	**41.913**	30.492	31.139	33.548	**31.726**
Volumetric Flow Rate								
acfm	1,031	1,003	990	**1,008**	449	427	488	**455**
dscfm	372	354	370	**366**	441	417	479	**446**
C3 Dimer Acid Emissions								
mg	315.028	471.959	281.478	**356.155**	2.3063	1.9683	2.7993	**2.3580**
mg/dscm	2.61E+02	4.01E+02	2.40E+02	**3.00E+02**	2.67E+00	2.23E+00	2.95E+00	**2.62E+00**
lb/hr	3.64E-01	5.32E-01	3.32E-01	**4.09E-01**	4.42E-03	3.49E-03	5.29E-03	**4.40E-03**
Removal Efficiency								
percent	**98.8**	**99.3**	**98.4**	**98.9**				
PFOA Emissions								
mg	**0.59626**	**0.59157**	**0.57470**	**0.58751**	0.00381	0.00362	0.00416	**0.00386**
mg/dscm	4.93E-01	5.03E-01	4.89E-01	**4.95E-01**	4.41E-03	4.11E-03	4.38E-03	**4.30E-03**
lb/hr	6.88E-04	6.67E-04	6.78E-04	**6.78E-04**	7.30E-06	6.42E-06	7.86E-06	**7.19E-06**
Removal Efficiency								
percent	**98.9**	**99.0**	**98.8**	**98.9**				

Appendix D.

Emissions Estimates from FEP Scrubber Inlets Lines 2 and 3 and Outlet Chemours Facility in Parkersburg West, Virginia

Sampled November 7, 2018

Table D-1. S*ample Mass For HFPO-DA and PFOA at the FEP Location Based on Test America Analytical Results*

HFPO-DA MASS per sample (µg/sample)							PFOA MASS per sample (µg/sample)						
Location	**Run**	**FH**	**BH**	**Impinger**	**XAD**	**Total Sample Mass**	**Location**	**Run**	**FH**	**BH**	**Impinger**	**XAD**	**Total Sample Mass**
FEP Line 2 Inlet	Run 1	1,040	1,850	103,000	5.2	105,895	**FEP Line 2 Inlet**	Run 1	1.80	9.48	102	0.035	113.31
	Run2	394	1,540	91,000	20.3	92,954		Run2	0.52	7.37	110	0.208	118.10
	Run3	286	2,950	95,200	55.2	98,491		Run3	0.83	12.5	115	0.213	128.54
	Average	573	2,113	96,400	26.9	99,114		Average	1.05	9.78	109	0.152	119.99
FEP Line 3 Inlet	Run 1	1,897	2,210	155,000	25.7	159,133	**FEP Line 3 Inlet**	Run 1	1.71	11.7	129	0.22	142.63
	Run2	896	3,143	92,900	19.3	96,958		Run2	1.50	13.9	85.7	0.08	101.18
	Run3	1,834	1,739	118,000	10.4	121,583		Run3	2.70	12.6	109	0.08	124.38
	Average	1,542	2,364	121,967	18.5	125,891		Average	1.97	12.73	108	0.12	122.73
FEP Outlet	Run 1	9.90	40.3	3.05	0.1	53.37	**FEP Outlet**	Run 1	0.315	0.562	0.0	0.0	0.877
	Run2	5.07	6.01	0.79	0.0	11.92		Run2	0.330	0.317	0.0	0.0	0.647
	Run3	7.39	13.2	2.73	0.0	23.36		Run3	0.360	0.413	0.0	0.0	0.773
	Average	7.45	19.8	2.19	0.1	29.55		Average	0.335	0.431	0.0	0.0	0.766

Table D-2. *Emission estimate for HFPO-DA and PFOA at the FEP Scrubber*

	FEP											
	FEP Line 2 Scrubber Inlet				FEP Line 3 Scrubber Inlet				FEP Scrubber Outlet			
	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Air Flow, as dry gas standard												
Collected Air Sample Volume During Test, expressed in ft^3 (dscf, ***Table D-3 OBG line 7***)	44.804	46.419	46.795	**46.006**	41.993	39.44	38.248	39.894	57.283	55.145	56.019	56.149
Collected Air Sample Volume During Test, expressed in m^3	1.269	1.314	1.325	1.303	1.189	1.117	1.083	1.130	1.622	1.562	1.586	1.590
Volumetric flow rate through pipe, expressed in ft^3/minute (dscfm, ***Table D-3 OBG line 10***)	279	289	288	285	506	487	451	481	1,745	1,716	1,730	1,730
Volumetric Air flow rate, expressed in m^3/minute	8	8	8	8	14	14	13	14	49	49	49	49
Analyte Concentration in Gas Volume Collected During Test												
HFPO-DA												
HFPO-DA Total Mass Measured in Samples					HFPO-DA							
HFPO-Da total mass measured in sample, µg/sample (***Table D-1***)	**105,895**	**92,954**	**98,491**	**99,114**	**159,133**	**96,958**	**121,583**	**125,891**	**53.4**	**11.9**	**23.4**	**29.6**
HFPO-DA total mass measured in sample, mg/sample	105.895	92.954	98.491	99.1	159.133	96.958	121.583	125.891	0.053	0.012	0.023	0.030
HFPO-DA total mass measured in sample, lbs/sample	2.33E-04	2.05E-04	2.17E-04	2.19E-04	3.51E-04	2.14E-04	2.68E-04	2.78E-04	1.18E-07	2.63E-08	5.15E-08	6.52E-08
HFPO-DA Concentration in Air = Total Mass ÷ Collected Air Sample Volume												
HFPO-DA Concentration (lb/ft^3)	5.21E-06	4.42E-06	4.64E-06	4.75E-06	8.36E-06	5.42E-06	7.01E-06	6.96E-06	2.05E-09	4.77E-10	9.20E-10	1.16E-09
HFPO-DA Concentration (mg/m^3)	8.35E+01	7.07E+01	7.43E+01	7.61E+01	1.34E+02	8.68E+01	1.12E+02	1.11E+02	3.29E-02	7.63E-03	1.47E-02	1.86E-02
PFOA												
PFOA Total Mass Measured in Samples					PFOA							
PFOA total mass measured in sample, µg/sample ***(Table D-1)***	**113**	**118**	**129**	**120**	**142.6**	**101.2**	**124.4**	**122.7**	**0.9**	**0.6**	**0.8**	**0.8**
PFOA total mass measured in sample, mg/sample	0.113	0.118	0.129	0.120	1.43E-01	1.01E-01	1.24E-01	1.23E-01	8.77E-04	6.47E-04	7.73E-04	7.66E-04
PFOA total mass measured in sample, lbs/sample	2.50E-07	2.60E-07	2.83E-07	2.65E-07	3.14E-07	2.23E-07	2.74E-07	2.71E-07	1.93E-09	1.43E-09	1.70E-09	1.69E-09
PFOA Concentration in Air =Total Mass ÷ Collected Air Sample Volume												
PFOA Concentration (lb/ft^3)	5.58E-09	5.61E-09	6.06E-09	5.75E-09	7.49E-09	5.66E-09	7.17E-09	6.78E-09	3.38E-11	2.59E-11	3.04E-11	3.01E-11
PFOA Concentration (mg/m^3)	8.93E-02	8.98E-02	9.70E-02	9.21E-02	1.20E-01	9.06E-02	1.15E-01	1.09E-01	5.41E-04	4.14E-04	4.87E-04	4.82E-04
HFPO-DA Emission Rate												
HFPO-DA Emissions Per Hour = HFPO-DA Concentration in Air x Volmetric Flow Rate x 60	HFPO-DA Produced at FEP Line 2 before Scrubber				HFPO-DA Produced at FEP Line 3 before Scrubber				HFPO-DA Released to Air from FEP after Scrubber			
lbs/hr	8.72E-02	7.66E-02	8.02E-02	8.13E-02	2.54E-01	1.58E-01	1.90E-01	2.01E-01	2.15E-04	4.91E-05	9.55E-05	1.20E-04
kg/hr	3.96E-02	3.47E-02	3.64E-02	3.69E-02	1.15E-01	7.18E-02	8.60E-02	9.11E-02	9.75E-05	2.23E-05	4.33E-05	5.46E-05
HFPO-DA Emissions Per Year												
lbs/yr	764	671	703	712	2,222.27	1,387.53	1,661.52	1,760.36	1.88	0.43	0.84	1.06
kg/yr	347	304	319	323	1,007.83	629.26	753.52	798.35	0.85	0.19	0.38	0.48
HFPO-DA Removal Efficiency = (Inlet -Outlet Emission Rate) ÷ Inlet Emission Rate x 100	**99.9%**	**99.98%**	**99.96%**	**99.96%**								
PFOA Emission Rate												
PFOA Emissions per Hour = PFOA Concentration in Air x Volmetric Flow Rate x 60	PFOA Produced at FEP Line 2 before Scrubber				PFOA Produced at FEP Line 3 before Scrubber				PFOA Released to Air from FEP after Scrubber			
lbs/hr	9.34E-05	9.73E-05	1.05E-04	9.85E-05	2.27E-04	1.65E-04	1.94E-04	1.96E-04	3.53E-06	2.66E-06	3.16E-06	3.12E-06
kg/hr	4.23E-05	4.41E-05	4.75E-05	4.46E-05	1.03E-04	7.50E-05	8.80E-05	8.88E-05	1.60E-06	1.21E-06	1.43E-06	1.42E-06
PFOA Emissions Per Year												
lbs/yr	0.8	0.9	0.9	0.9	1.99	1.45	1.70	1.72	0.03	0.02	0.03	0.027
kg/yr	0.4	0.4	0.4	0.4	0.90	0.66	0.77	0.78	0.01	0.01	0.01	0.012
PFOA Removal Efficiency (%) = (Inlet -Outlet Emission Rate) ÷ Inlet Emission Rate x 100	**98.9%**	**99.0%**	**98.9%**	**98.9%**								

Table D-3. *OBG Engineering Report for the FEP Scrubber*

Table 3
The Chemours Company - Washington Works
FEP Scrubber Emissions
Parkersburg, West Virginia

Run Identification	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average	Run 1	Run 2	Run 3	Average
Run Date	07Nov18	07Nov18	07Nov18		07Nov18	07Nov18	07Nov18		07Nov18	07Nov18	07Nov18	
Start/Stop Time	1055-1155	1325-1425	1540-1640		1055-1155	1325-1425	1540-1640		1055-1155	1325-1425	1540-1640	
Source ID	Line 2 Scrubber Inlet				Line 3 Scrubber Inlet				Scrubber Outlet			
Exhaust Gas Conditions												
Temperature (deg. F)	228	211	218	**219**	194	190	193	**192**	61	59	61	**60**
Moisture (volume %)	21.5	21.9	22.8	**22.1**	21.6	17.9	22.6	**20.7**	1.5	1.4	1.1	**1.3**
Oxygen (dry volume %)	20.0	20.0	20.0	**20.0**	20.0	20.0	20.0	**20.0**	20.0	20.0	20.0	**20.0**
Carbon Dioxide (dry volume %)	0.10	0.10	0.10	**0.10**	0.10	0.10	0.10	**0.10**	0.10	0.10	0.10	**0.10**
Collected Sample Volume												
dscf	44.804	46.419	46.795	**46.006**	41.993	39.440	38.248	**39.894**	57.283	55.145	56.019	**56.149**
Volumetric Flow Rate												
acfm	463	471	480	**471**	801	730	722	**751**	1,735	1,698	1,715	**1,716**
dscfm	279	289	288	**285**	506	487	451	**481**	1,745	1,716	1,730	**1,730**
C3 Dimer Acid Emissions												
mg	105.895	92.954	98.491	**99.114**	159.133	96.958	121.853	**125.981**	0.05337	0.01192	0.02336	**0.030**
mg/dscm	8.35E+01	7.07E+01	7.43E+01	**7.62E+01**	1.34E+02	8.68E+01	1.13E+02	**1.11E+02**	3.29E-02	7.63E-03	1.47E-02	**1.84E-02**
lb/hr	8.72E-02	7.65E-02	8.01E-02	**8.13E-02**	2.54E-01	1.58E-01	1.90E-01	**2.01E-01**	2.15E-04	4.91E-05	9.54E-05	**1.20E-04**
Removal Efficiency												
percent	**99.8**	**99.9**	**99.9**	**99.9**								
PFOA Emissions												
mg	0.11331	0.11810	0.12854	**0.11999**	0.14263	0.10118	0.12438	**0.12273**	0.00088	0.00065	0.00077	**0.00077**
mg/dscm	8.93E-02	8.98E-02	9.70E-02	**9.21E-02**	1.20E-01	9.06E-02	1.15E-01	**1.08E-01**	5.41E-04	4.14E-04	4.87E-04	**4.81E-04**
lb/hr	9.33E-05	9.72E-05	1.05E-04	**9.83E-05**	2.27E-04	1.65E-04	1.94E-04	**1.95E-04**	3.53E-06	2.66E-06	3.16E-06	**3.12E-06**
Removal Efficiency												
percent	**96.2**	**97.3**	**97.0**	**96.8**								